LoRa Based Vehicular Communications

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Abstract*: Past few years road traffic is increasing at an alarming rate. Traffic congestion, wasted time at traffic lights, and increased air pollution is part of the consequences of increased traffic. Traditionally the traffic lights are not smart and the communication between them is also not happening. Cooperative navigation and monitoring can be easily done by the inclusion of LORA Technology in Vehicular communication. With the help of LoRa technology, the Low Power consumption network can be established for large coverage area. In this paper authors analyze the LoRa- based traffic and the emergency vehicle detection scheme. We conduct the Performance analysis of the LoRa technology using the experimental and simulated setup in urban mobility environment. We also conduct field test on two scenarios along with the simulation done using network simulator NS-3 simulations. The result determines the effect of the Spreading factor SF used in analyzing the RSSI and PDR as the metrics of interest.

***Keywords*: LoRa, Packet delivery Ratio, Performance analysis.**

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I. INTRODUCTION

In recent years, RF communications have continued to make progress which allows low-power communications to cover long distances. (Long Range Radio) LoRa does not require complex deployment and it is multi hop technologies that permit communication up to kilometers. The LoRa based network have been set up in indoor urban environment and in the mountain scenario.

With the growing research on the (internet of Things) IoT based application the Lora technology found its way in the smart cities and smart roads. One important application where the use of LoRa is researched is the traffic flow detection and monitoring [2, 3, 4]. Camera based approach is also used for the vehicle detection and classification. The camera-based approach used various cameras to analyze the scenario. Regardless of the lower number of camera, installation, maintenance and privacy related problems are present in the current scenario. The successful monitoring of traffic also includes other sensors, such as a magnetometer and accelerometer in various application scenarios. Other technology such as Radio Tomographic Imaging (RTI) has proved to be more accurate in the different environment. It uses 2.4 GHz (Wireless Fidelity) WI-Fi signal to locate the people. The different technologies related to WIFI and ZigBee signals to detect the traffic flow, various vehicle classifications and the speed monitoring can also be done using LoRa implementation. The Lora technology is reliable for different setup in outdoor experiments, it shows a relation between environmental conditions, (Received Signal Strength Indicator) RSSI, packet reception rate. Various vehicle classifications and the speed monitoring can also be done using LoRa implementation. The Lora technology is reliable for different setup in outdoor experiments it shows a relation between environmental conditions, (Received Signal Strength Indicator) RSSI, packet reception rate. RSSI is evaluated in the LoRa based localization. Close participation between the infrastructure and vehicles are in demand. In [6, 7] author states (Network Simulator version 3) NS-3 helps to perform various types of simulation of LoRa Based network.

II. RELATED WORK

In [10] author states the comparison study of the different (Low power Wide Area Network) LPWAN technology. The authors also demonstrate the application of Lora technology in temperature controller for the building. In [11] authors proposed the hybrid model using the Wi-Fi and Lora technology for public transport tracking. In the given research authors compare the two modes of communication with tracking and monitoring of vehicles and also incorporate the techniques in Cooperative communication scenario. In [12] the authors proposed the use of vehicular communication mode of V2V and V2I using the Lora technology. For both indoor and outdoor environment authors in [13] used the LPWAN technology for data transfer. In [14] author states that the LoRa technology-based vehicle detection and diagnostic system was designed and In [15] author also proposed the application of LoRa as wireless technology for bus location systems which was implemented in Japan. In [16] author states the LoRa technology and find its application in parking allotment and management system. In [17] the LoRa technology-based system is designed by authors to investigate its robustness across Doppler Effect. In [1] author states about the LORASim which is a tool based on event-based simulation. The gaps and challenges faced are uncommon in traffic detection in different environment which leads to the formulation of problem statement Is there any scheme to describe the traffic management scenario and also helps in detection of the Emergency situation as Accident on road, emergency vehicle detection using LoRa Technology.

III. LONG RANGE (LORA) DATA TRANSMISSION MODEL

In this paper the authors have come out with the scheme and is described in different sections. Section2 which discusses work related to application of LoRa technology in different application domain . Section3 briefly describes the LORATED scheme and about the LoRa Technology Section 4 provides the performance Evaluation of the LoRa Technology Based scheme and its real testbed results which fulfill the gaps and challenges stated in the problem statement above. Section 5 provides the conclusion and also suggests the future scope of the present work

A. Data Dissemination Based On LoRa Technology

Figure 1 depicts an implementation of a vehicular Communication system based on components and their interaction. We present architecture for a message transmission device using Lora. The Real time experimental setup consists of Arduino development board attached with GPS sensor, Pycom LORA board and Dragino Lora module.

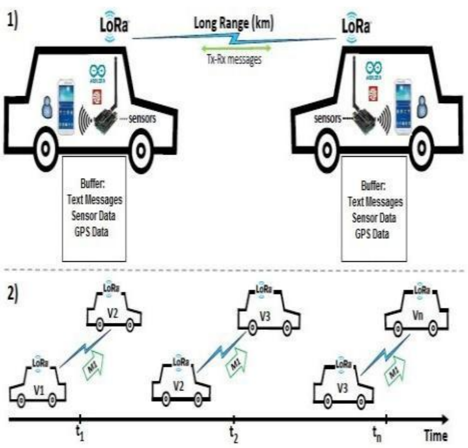

Fig. 1. Interaction between devices on vehicles using the LoRa Technology.

B. LORATED scheme

LORATED scheme is a LORA based technology scheme used in vehicular mobility scenario for the Traffic and Emergency vehicle Detection.

Figure 2 illustrates the activity of LORATED scheme.

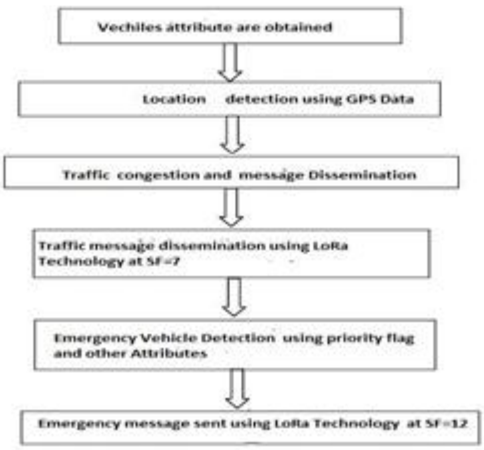

Fig. 2. Activity chart of LORATED scheme

Each vehicle is defined by different node id as V1, V2, V3 ….Vn. Each vehicle is attached with GPS sensor and LoRa

Supported Unit. The traffic information and the information related to emergency vehicles can be transferred to vehicles or road side infrastructure using LoRa technology. The information related to traffic flow and emergency vehicles are spread to other devices at the different rate depending on their priority. On detection of emergency vehicle at the junction a faster message is transferred to other traffic lights at the other junctions to make a green wave for the emergency vehicle to travel to its desired destination.

The identification of emergency vehicle is done by Road side infrastructure based on the priority flag and other emergency vehicle attributes. These attribute was helpful in finding the current position and distance from the junction. The details of emergency vehicles message are sent with different SF value as compared to sending the normal traffic messages are sent at different value of (Spreading Factor) SF.The first step of the LORATED Scheme was to provide the following information (1) Gathering of Floating data from vehicles (2) Detection of vehicles within the range of road side infrastructure.

The second step was to detect the traffic condition at the junction. We check the number of vehicles at the junction must be less than the maximum range, if it satisfies then the roadside infrastructure will generate the information about Normal Traffic message and sent to other vehicles and other infrastructure using LoRa technology with SF=7, and provide better power consumption and desirable range also.

The third step was to determine the Emergency vehicle detection and the faster data dissemination to long range. The emergency vehicle attributes are checked and then road side infrastructure will generate the information on Emergency vehicle detected message and sent to other vehicles and other infrastructure using LoRa technology with SF=12, and provide best range .The maximum range is obtained to provide information to the traffic lights installed at other junction to become green for the travel of Emergency vehicle the condition will be unaltered and normal traffic message signal will be sent By using LoRa technology at SF=7.

LORATED Scheme:

Step 1: Vehicle Attribute obtained
Attribute → Stored vehicles
information; {
Obtain distance from GPS location;
}

Step 2: **Checking Traffic Status**
Check for the entire vehicle in
Range {
Message Dissemination through LoRa WAN Technology;
Normal Traffic Message Sent (with parameter change of SF 7);
}
Else

{

Congestion Ahead Message Sent (with parameter change of SF 12);

}

Step 3:

Emergency Vehicle Detection

Attribute of vehicle → priority flag, id;

Check for the entire vehicle in Range

{
Vehicle Match = detect (Attributes of vehicle); if (Vehicle Match ! = priority flag) {

No emergency vehicle detected;
Normal Traffic Message Sent (with parameter change of SF 7);
}
else
{
Message of Emergency vehicle detected (with parameter change of SF 12);
Traffic signal Message Sent (with parameter change of SF 12);
}
Vehicle traffic act as normal;
}
End

C. LoRa Technology

Carrier frequency, spreading factor, Code rate (CR) are parameters of consideration in LoRa technology. The center frequency of the band of transmission is defined by carrier frequency. The frequency range defines the range of frequency which will be taken as 125KHZ, 250 KHZ and 500KHZ depending upon the various application scenarios. The chirp is used to represent the symbol and with the help of the SF parameter we determine its value [7, 8]. The relation between bit rate and chirp rate is established. Different SF parameters can be used within the range of SF (7-12) [9]. Higher value of SF gives better reception, but it increases the (Time on Air) TOA [3].

Better selection of SF will be done to reduce the Response time of the network. The SF directly effects the TOA. The higher value of SF will lead LORA Module to take more time to send, from transmitter to reach the receiver and is helpful in the calculation of TOA. The time taken for the calculation of TOA is defined in the equation 1 given below [9].

$$T_{sym} = \frac{2^{SF}}{BW}, \quad \text{with } SF \in \{7-12\}. \qquad (1)$$

According to Table 1 for different value of SF with C/R=4/5 and Bandwidth of 125 KHZ various value of the TOA is obtained. The LORA performance tests were done when the maximum allowable transmitted power is sent and it allows till 14.1 dBm. The two cases are considered with BW=125, C/r=4/5 and SF=7 and in the second case the values are BW=125, C/r=4/5 and SF=12. From the first case it leads to better power consumption and in the second case it translates to the maximum range. We consider that the devices at both the transmitter and receiver end for the uplink and downlink will have the same transmission power and receiver sensitivity.

TABLE I. DIFFERENT VALUE OF SF AND VALUE OF TOA

Spreading Factor	ToA (ms)
SF7	41
SF8	72
SF9	144
SF10	288
SF11	577
SF12	991

IV. EXPERIMENT AND PERFORMANCE EVALUATION

After the Various parameters such as speed, SF and distance are varied to perform the real time experiments. The RSSI measurements are carried out along with the (Packet Delivery Ratio) PDR which is analyzed with change in distance and speed. The realistic environmental measurements are performed using hardware prototype and simulation was performed on NS3 where LORAWAN library is implemented and the necessary parameters are varied as per the environment.

Two scenarios are tested under experimental scenario 1. Maximum coverage range with static nodes. 2. Max mobility range with the movable node. In Scenario 1: The receiver is marked with a red marker and it is static which is placed on the first floor of the building (40 ft from the ground) and the transmitter send the message to the receiver. Figure 3. depicts the continuous data is sent from the transmitter at a distance of 550m , 1100m, 1500m ,2200m and 2500m which are marked with different points in Figure 3 . Table 2 shows the distance between different points. The value of SF (7, 9, 12) is varied and we check the reading of RSSI with distance. In Scenario 2: The impact of mobility is studied. In the given scenario the prototype is placed in the car and it is moving at different speeds. The 800m and 700m road segment are taken for the test bed. The car transmits the message at a constant rate with the packets are send at the different SF (7, 9, 12) and behavioral study of LORA was conducted as function of speed and distance. Table 3 show he configuration for the Experimental setup.

TABLE II: RELATION BETWEEN DISTANCE AND DIFFERENT ROAD SEGMENT

Segment	Distance (m)
RX----A	800
A-----B	700
B-----C	1000
B------D	1000
B-----E	1000

TABLE III: THE LORA CONFIGURATION

Parameter	Setup	Experimental	Simulated
Frequency	868 MHz	✓	✓
Tx power	14 dBm	✓	✓
Spreading Factor (SF)	(7-12)	✓	✓
Bandwidth	125 kHz	✓	✓
Code Rate	4/5	✓	✓

In the experimental mode data collected in the receiver about the GPS coordinate and id of the vehicle sent through LORA and identified the priority flag for the emergency vehicle detection. For each transmission data the 18 byte data is sent in each cycle. The RSSI measurement can be obtained without using any external device only software library pack is used in both hardware prototype and in NS3 simulation. There is a variation of the(Received Signal Strength indicator) RSSI level despite communication is within the LOS. The figure shows the RSSI level with distance using LORA transmission at various values of SF (7, 9, 12).

RSSI level-based heat map is generated along the three road segment is shown in Figure 3 we compare the effect of SF and speed variable which is taken as 20-30 km/h. There is some portion which is totally blackout. The given Figure 4 shows the graph of RSSI with the distance with different value of SF(7, 9,12) along the road segment of (RX---A—B—C) f very low reception which is demonstrated by an absence of a transmission , In these areas it is very difficult to send the message of immediate response time. The emergency vehicle detection is not possible in the given scenario also and very difficult to send high priority messages also. The given figure 4 shows the graph of RSSI with the distance with different value of SF(7,9,12) along the road segment of (RX---A—B—C) The given figure 5 shows the graph of RSSI with the distance with different value of SF(7,9,12) along the road segment of (RX---A— B—D) The given figure 6 shows the graph of RSSI with the distance with different value of SF(7,9,12) along the road segment of (RX---A—B—E) we compare the RSSI graph in real time and simulated environment they show the similar behavior.

Fig. 3. The RSSI level heat map for different segment of road with distance.

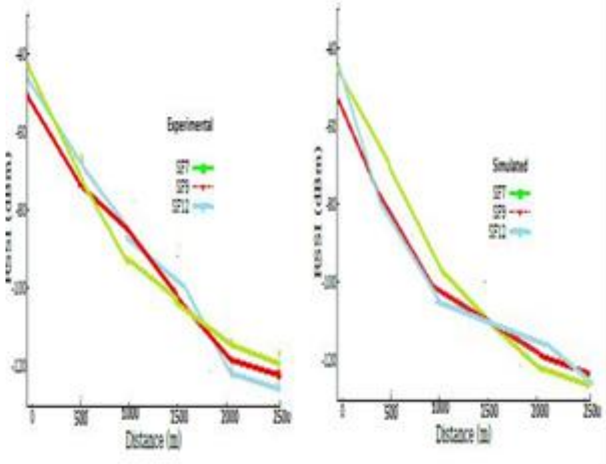

Fig. 4. The RSSI level with distance using LORA transmission at various values of SF(7,9,12)in road segment Rx—A---B---C

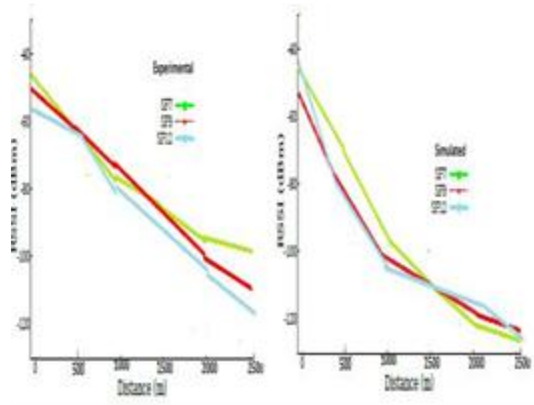

Fig. 5. The RSSI level with distance using LORA transmission at various values of SF (7,9,12) in road segment Rx—A---B---D

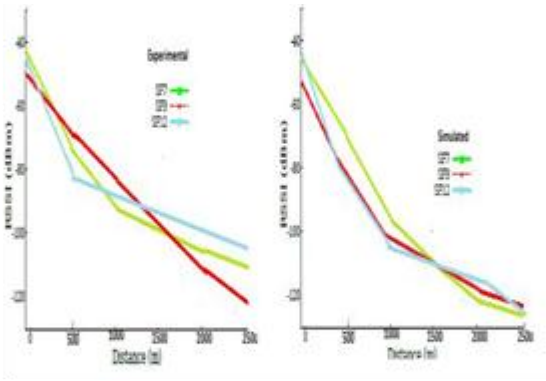

Fig. 6. The RSSI level with distance using LORA transmission at various values of SF (7,9,12) in road segment Rx—A---B---E

The given figure 7 shows the graph of PDR with the distance with different value of SF (7,9,12) when we compare the PDR graph in real time and simulated environment, they show the similar behavior. The PDR decreases gradually with the change in the RSSI value over the given distance.

The interpretation is PDR decreases in all the SF value as the distance increases and where we have observed the low RSSI value also. The figure 7 the PDR is 80% from 1500m to 2000m and from the RSSI vs. Distance graph also we conclude that the distance over 1500m from the receiver the RSSI value is less than -90dBm and the signal strength decreases afterwards.

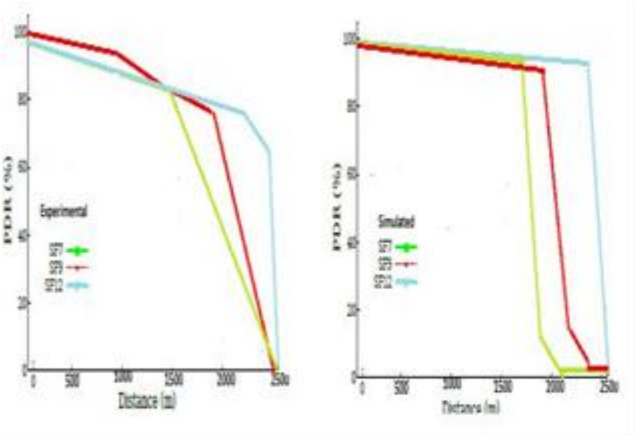

Fig. 7. The graph of PDR with the distance with different value of SF (7, 9, 12)

Experimental setup for mobility configuration: The 800m road segment B-C is shown in figure 8 we compare the effect of SF and speed variable which is taken as 20-30 km/h. In the given experimental setup, we divide a road segment into small segments of 100 m as seen in figure 8. The authors observe the effect of urban vegetation and physical structure of the RSSI value and the link quality. From Figure 9 we observe that within covering 300 m considerable decrease in the RSSI value as we can see the buildings and other physical structure around the road segment.

The vegetation and infrastructure change the link behavior characteristics. The figure 9 shows that where SF9 is selected it gives the maximum range was 800m but only 15% PDR at 800m.

Fig. 8. Mobility scenario experimental setup where road segment divided into small segment of 100 m

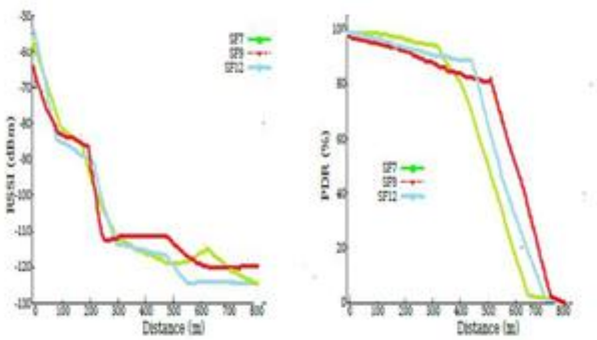

Fig. 9. The graph of RSSI and PDR with the distance with different value of SF (7, 9, 12)

The 700m road segment B-D is shown in figure 10 we compare the effect of SF and speed variable which is taken as 20-30 km/h. Now again in this scenario of experimental setup we divide a complete 700m road segment into small segments of 100 m as seen in the figure . We observe the effect of urban vegetation and physical structure of the RSSI value and the link quality. Now from figure 11 we observe that within the coverage of 450 m the RSSI does not decrease and the link quality is stable there is open field around the road segment. The vegetation and infrastructure change the link behavior characteristics again between 450 m to 700m. The figure 11 shows that where SF9 is selected the maximum range was 700m but only 20% PDR at 700m.

Figure10: Mobility scenario experimental setup where road segment divided into small segment of 100 m

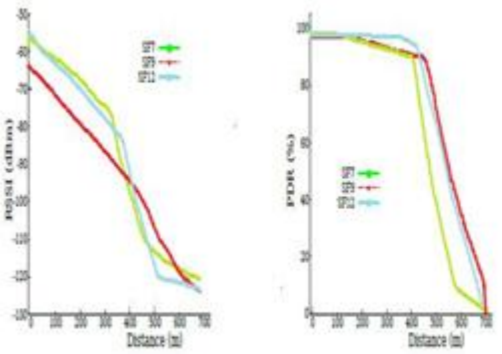

Figure11:The graph of RSSI and PDR with the distance with different value of SF(7,9,12)

V. Conclusion and Future Work

The performance evaluation and implementation of Emergency vehicle detection scheme using LoRa technology was done. Performance evaluation of a simulated environment was also done where the two different scenarios were compared: one with range evaluation and another with mobility scenario of the vehicle. Parameters of LORA technology such as distance spreading factor (SF) and speed levels which are analyzed in both the scenario. Comparative analysis based on the RSSI level and PDR variables for the collected data was done. The impact of both high speeds, propagation models for different areas will be investigated for the implementation of the given scheme in the coming future work.

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